PANORMORPH FOR SMARTPHONES & TABLETS
THE PANOMORPH TECHNOLOGY

Mathieu Villegas and Pierre Sergerie
ImmerVision
2020 University St., Montreal, Canada H3A 2A5
And
Simon Thibault MSc, PhD, ing.
Principal Optical Designer at ImmerVision,
Professeur Adjoint, Département de physique, génie physique et optique
Université Laval, Québec, Canada

I. INTRODUCTION

In today's business world, mobility is king and video is the new way of communicating. Video conferencing is booming and estimated to be a $34B industry. We are just around the corner from **video collaboration "everywhere"**. Well-known companies are investing heavily to capture their "unfair" share (Cisco, Microsoft, HP, Skype, Polycom, etc.) of this booming industry. Mobile Network Operators are investing in faster networks and new technologies to increase speed, quality and reach. Video conferencing represents an interesting avenue to monetize their bandwidth as well as leverage their network improvement investments (LTE, HSPA+, etc.).

Video chat, Video calling, Video conferencing via smartphone exist today. However, there are limitations with available technology (embedded front facing cameras have narrow field of view, participants' position in front of the camera, number of participants able to participate, as well as the inability to move about a room or navigate the view). Panomorph technology takes the video conferencing experience to a new level and represents a disruptive opportunity in deploying true 360° technology to the Mobile community worldwide**. It is disruptive, fun, cost effective and easy to deploy**.

This paper will present how an ImmerVision invented 360° Panomorph lens coupled with its immersive viewing functionality embedded in smartphones and tablets can make quality **video conferencing "on the go"** a reality today.

We will demonstrate how the wide angle field of view (180°x360°), augmented resolution, close focus and distortion free imaging software can improve the video conferencing experience.

1) One camera, one video feed, captures 180° X 360°
2) Allowing 360° video – live or playback mode (office, home, ``on the go``, etc.)
3) **Flexibility in your movement** – no limitations to a fixed narrow angle of view
4) <u>Multiple usage possibilities – sitting at a table, walking, hands free in a car, etc.</u>
5) **Multiple participants, same camera, free to move around the room**
6) <u>Head tracking system</u> – possible and easy
7) Simultaneous viewing possibilities – linear, individual head shots, etc.

II. WHAT IS THE PANOMORPH TECHNOLOGY

The goal of Panomorph technology is to combine the advantages of both narrow angle and wide angle lenses in a single system.

The Panomorph technology is composed of two elements:

- Optical Element: a Panomorph lens, which is usually not a symmetric wide angle lens (Field of view > 140°), that has no blind spot and considers lens distortion and camera sensor shape as design parameters to maximize sensor coverage and optimize the magnification in the areas of interest
- Software Element: an unwarping algorithms (software library) designed to unwarp (remove distortion) images created by Panomorph lenses, allowing one to retrieve and leverage all the information captured by the optical system (panomorph lens + sensor), maximizing sensor coverage and optimizing resolution in areas of interest. Furthermore, the software allows the viewer to navigate in the 360° of the panomorph images or videos and select his viewing options

The unwarping algorithms can be easily integrated in any software to unwarp Panomorph images and provide:

- Unwarped views with or without specific distortion easily understandable by a human brain
- Unwarped views with specific distortion to ease the analysis with an analytic software
- Unwarped views in a format easy to store, retrieve, manipulate or manage for a software or a human

III. THE PANOMORPH LENS

A. INCREASE OF RESOLUTION BY OPTIMIZING SENSOR SURFACE COVERAGE

In the world of Using old technology in panoramic imagery and wide angle lenses, the image footprint created by reflective or refractive optical systems has always been circular (Figure 1). Considering that most of the sensors on the market are rectangular, these systems were using a limited amount of the pixels available on the sensor (59%), losing a lot of resolution and information the sensor was able to provide.

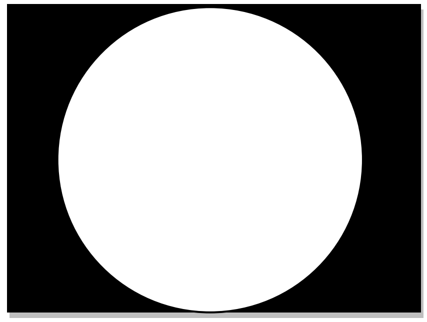

Figure 1: on a 4/3 ratio sensor, the circular footprint of a standard optical system covers only 58.9% of the pixels

Panomorph lenses take into consideration the fact that sensors are not squares and are designed to expand the image footprint along the entire vertical and horizontal axes of the sensor. This improvement allows the panomorph lens to cover at least 33% more resolution while keeping the whole 180x360 field of view, compared to any other wide angle optical system with the same 4:3 aspect ratio sensor (Figure 2).

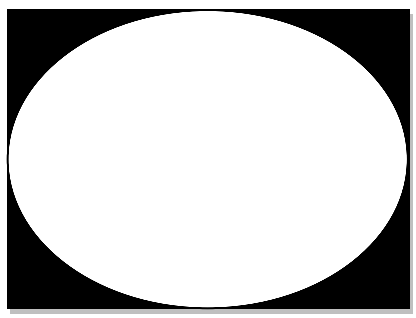

Figure 2: Panomorph image footprint covers 78.3% of the pixels

The trend in sensor and display technology is going to higher aspect ratio (e.g. 16:9, 16:10, etc.), making the gain provided by the panomorph technology much more significant on this type of imaging device.

B. INCREASE RESOLUTION IN THE AREA OF INTEREST BY DISTORTION CONTROL

Unlike other refractive lenses, the Panomorph lens considers optical distortion as a way to increase the optical resolution of a system in the area of interest. By managing distortion efficiently, the panomorph lens is able to spread the resolution along the sensor surface in the way required to fit the viewing requirements for a specific application.

Below, find more details pertaining to a video conferencing scenario. In such usage, the device (smartphone or tablet) equipped with a panomorph lens set on a table, facing up, with the attendees sitting around the table.

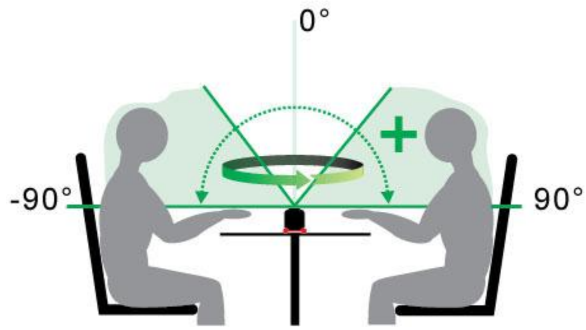

Figure 3: Video conferencing

Figure 3 depicts how the panomorph lens brings more resolution to the periphery (**green area**) and less in the area directly above the lens. To provide this highest resolution in the green area, the Panomorph lens is designed to increase the angular resolution near the periphery of the image.

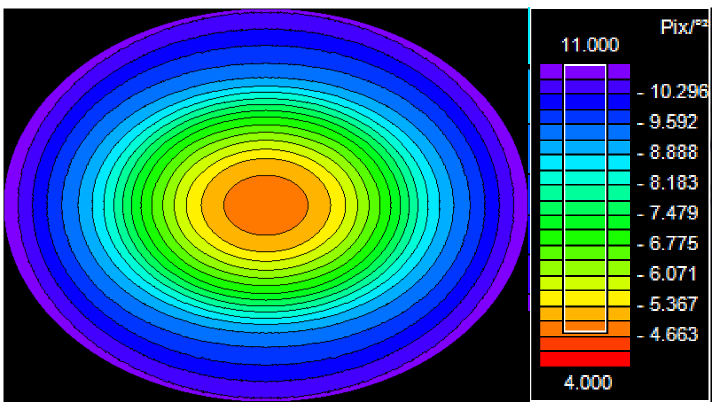

Figure 4 a) Example of Panomorph resolution distribution for video conferencing [1]

Figure 4 b) actual rendered image using resolution curve shown in 4a) [1]

Figure 4 a) above shows the actual distribution of pixels to match application requirements (as per Figure 3, while 4 b) is the actual elliptical image rendered. We can see that the resolution on the periphery of the lens is higher than in the centre. This is by design, in order to provide as much quality as possible where required, based on application requirements. The resolution on the periphery is up to three times higher than the middle.

The radial resolution curve corresponding to this lens is displayed in figure 5 below.

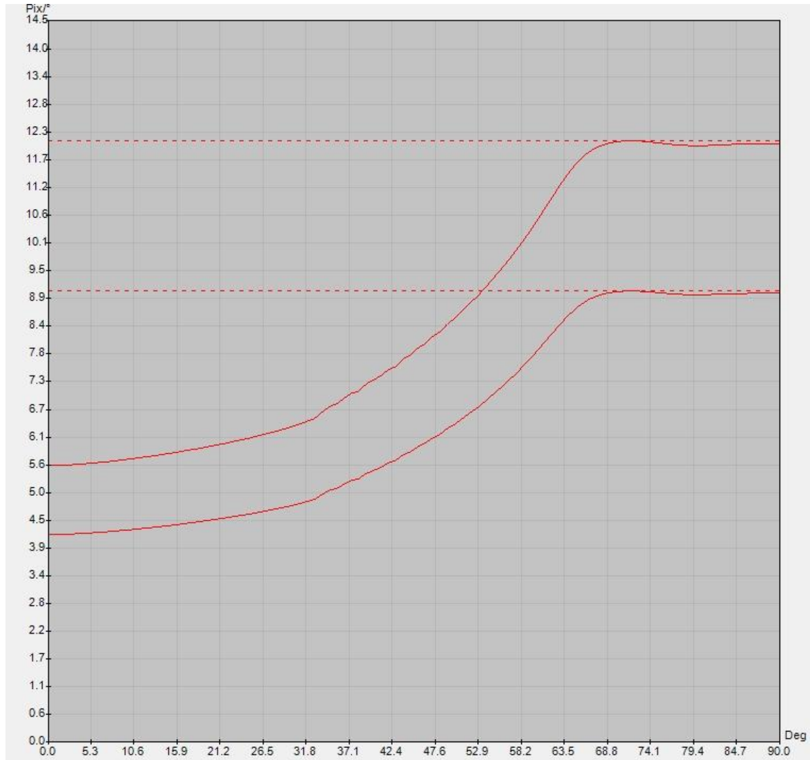

Figure 5: Radial resolution for short and long axes [1]

Since the image created by the panomorph lens is not circle, but an ellipse, we have two different curves (Figure 5) corresponding to the two main axes (vertical/short and horizontal/long).

C. PANOMORPH LENS DESIGN

During the last few years, it has been demonstrated that a Panomorph lens can be built to replace a regular lens in various applications to provide a 180-degree field of view. From an optical design point of view, we can consider some aspects which are unique to smartphone or tablet applications. The scale of a smartphone or tablet camera module creates unique challenges for lens designers. When designing such a wide angle lens, it is not always helpful to use a traditional larger scale lens as a starting point. Scaling down the lens will result in elements that cannot be manufactured. For example, the element thickness can become too thin to be fabricated.

The development of sensors has been moving towards smaller pixels and higher density formats. The higher resolution formats in the smartphone sensor have made the lens designer’s job extremely challenging, because reduction of pixel size has required an increase in lens performance. The lens performance requirements are closer to the diffraction limits and the lens tends to be more sensitive to misalignment. Another problem with small pixels is the limited light collection ability. The sensor surface is not uniformly sensitive. Circuitry integrated with the sensor reduces the active area significantly. To improve sensitivity, an array of micro lenses located above the active area of the sensor is applied, but this will also impose a chief ray angle (CRA) specification on the lens design. The CRA is the angle of incidence of the chief ray at the image plane for any field point. The micro lens acts as a condenser, relaying the sensor image to the exit pupil of the micro lens. This increases the apparent pixel size.

The total track length (TTL) of the lens (from first optical surface to sensor) is also an important factor for miniature optics. The TTL of smartphone cameras becomes smaller and smaller. Panomorph lens TTL can be smaller than 4.5 mm. In general, the panomorph lens is about two times longer than a 30 degree lens. Consequently, the panomorph lens can meet size requirements in smartphone industries. To see 180 degrees, the Panomorph front element must exceed the lens housing, but the extra space can be as small as 0.4 mm.

As part of the design process, material selection is critical. Plastic injection moulded optics can be a good choice. Keeping in mind manufacturing limits, plastic has the big advantage that the flanges can be moulded to eliminate the need for spacers and allow for mechanically driven centering of one element to another. One disadvantage is that there are very few plastic materials (low and limited index of refraction), so the choices are limited. Another option available is moulded glass, providing the advantages of both high index and aspheric corrections. The manufacturing process is more complicated and less flexible than with plastic, nevertheless moulded glass can be the material of choice when the goal is stability and color correction for higher resolution lenses.

Lens performance for digital vision systems is commonly expressed in terms of MTF at spatial frequencies between Nyquist/2 (Ny/2) and Nyquist/4 (Ny/4). The Nyquist frequency is (2 X pixel size)-1. So for a 5.6 um pixel, Ny/2 is 45 lp/mm; for a 2.2 um, Ny/2 is 113.6 lp/mm; and for a 1.75um, Ny/2 is 142.9 lp/mm. The size of the sensor is not as critical as the pixel pitch for the design of a panomorph lens.

IV. THE PANOMORPH SOFTWARE

The software is closely linked to the design and the function of a panomorph lens for a specific application. The main role of the software in the panomorph philosophy is to retrieve and exploit the increase of resolution created by the panomorph lens design, while removing the distortion to provide a human brain friendly view. It can be considered as a sort of virtual camera allowing one to move in a Panomorph image environment, while providing many more possibilities than a standard camera could offer.

With 10 years of software research and development, ImmerVision has built advanced and powerful algorithms adapted to all kinds of embedded system requirements and designed to ease the setting and unwarping of panomorph pictures with limited system resources.

ImmerVision library:

- Is light: a few kilobytes in size (the size varies depending on the functionalities required)
- Has an automatic lens calibration system
- Comes as a static or dynamic library

- Doesn't depend on third party libraries
- Works on any standard or embedded OS: Windows versions, Linux, MacOSX, iOS, Android, etc.
- Works on many different architectures, like standard computers processors (x86, x86_64, PowerPC, GPU, etc.), or low power embedded processors (ARM, DSP, GPU, FPGA etc.).
- Works with floating point optimized architecture (ex: GPU) or integer optimized ones (ex: DSP)
- Can be used with many different programming languages: C, C++, C#, Visual Basic, Java etc.

For Smartphones or tablets, ImmerVision Panomorph unwarping library can run using the CPU, the GPU or the DSP, depending on platform constraints and other software requirements.

The software library is able to provide a wide variety of renderings adapted to a variety of applications. Below are two kinds of unwarping adapted to a conferencing scenario, as described above.

Figure 6: Picture created by the Panomorph lens. Blue areas represent the views displayed in Figure 7, and the red one the views displayed in Figure 8

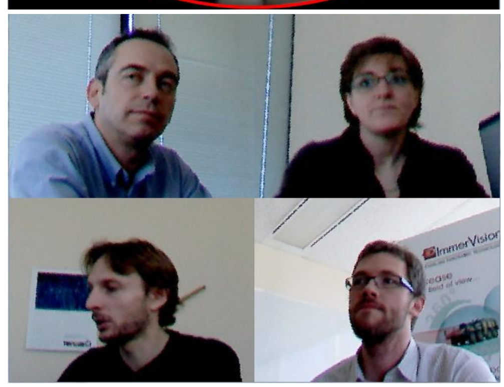

Figure 7: standard 4 unwarped PTZ views

Figure 8: single picture 360° view made of two strips of 180°

V. CONCLUSION

By combining a) the optimization of the sensor surface coverage, b) the ability to increase the resolution in areas of interest and c) a light, versatile and customizable viewing software algorithm, ImmerVision Panomorph 360° Technology provides a very powerful, flexible and cost effective way to enable panoramic technology on board Smartphones and Multimedia Tablets for applications such as Video conferencing.

VI. References

1. Simulated lens images and graphics in this publication were created using ImmerVision Panomorph Geometrical Model Simulator

2. S. Thibault, Panomorph Based Panoramic Vision Sensor, Vision Sensors and Edge Detection, edited by F. Gallegos –Funes, Chapitre 1, pp. 1-28, ISBN 978-953-307-098-8, 2010.

3. Artonne, JC. , Moustier, C., Blanc, B., (2005) US Patent 6,844,990. Method for capturing and displaying a variable resolution digital panoramic image, issued, January 18, 2005.

4. Moustier, C., Blanc, B., (2005) US Patent 6,865,028. Method for capturing a panoramic image by means of an image sensor rectangular in shape, issued, March 08, 2005

5. ImmerVision Lab, Panoramic 360-degree panomorph fix webcam, Youtube Video http://www.youtube.com/watch?v=GQD8uTXkNVo, 2008